



FOREST PEST MANAGEMENT

Pacific Southwest Region

LAT 39.16293 LON -120.23763

3420 Pest Management Evaluation
September 26, 1989

A BIOLOGICAL EVALUATION OF PEST CONDITIONS AT ALPINE MEADOWS SKI AREA, TAHOE NATIONAL FOREST

Report No. 89-18

Susan Frankel, Plant Pathologist
and
Dennis Hart, Entomologist

ABSTRACT

Alpine Meadows ski area on the Truckee Ranger District, Tahoe National Forest, was evaluated for the presence of diseases, insects and overall stand health and vigor. Red fir dwarf mistletoe (Arceuthobium abietinum f.sp. magnificae), annosus root disease (Heterobasidion annosum), fir engraver (Scolytis ventralis), and man-caused injury were most damaging. Alternate placement of snow making equipment, potential for salt damage and control of pests are discussed.

INTRODUCTION

On July 26 and 27, 1989, Plant Pathologist Susan Frankel, and Entomologist Dennis Hart, Forest Pest Management, Regional Office, evaluated the health and pest status of the trees at Alpine Meadows ski area. They were accompanied by Rick Maddalena, Recreation Officer, Truckee Ranger District, Tahoe National Forest, and Robert Blount, Mountain Manager and Sam Harris, Snow Making Supervisor at Alpine Meadows.

The evaluation was prompted by observations by ski area and Forest Service personnel that an unusually high number of trees were dead and dying in the area (see Fig. 1). The objectives of the evaluation were to determine the causes of the mortality and to provide pest management alternatives that may

minimize future tree losses while maintaining a safe and aesthetically pleasing ski area.

OBSERVATIONS

Alpine Meadows is located near the north shore of Lake Tahoe outside of Tahoe City. It encompasses 2000 skiable acres, accessible from 13 chairlifts on a mixture of private and National Forest land. More than 300 acres are groomed and 160 acres have snow making equipment. Base elevation is approximately 7000 feet, reaching a high of 8637 feet at Ward peak and 8289 feet at Scott Peak.

Four areas of concern to the Ski Area Manager and the Forest Service Recreation Officer new evaluated. A description of the stand and pest conditions in each of these areas follows. More information about the pests listed here is contained in the Management Alternatives and Pest Biology sections of this report.

1. Area adjacent to Tiegel Poma (elevation 7000 feet).

The area, approximately 2 acres, extends from the creek to the poma lift. The multi-storied stand is comprised of a mixture of red fir, white fir, lodgepole pine and western white pine. Regeneration, primarily fir with some lodgepole pine, is plentiful in spots. Basal area is approximately 360 sq. ft. per acre. The overstory is dominated by 36 to 50-inch dbh red fir. Trees have been removed for road and ski run construction and there are large stumps in the area.

Several pests were observed impacting trees in the area. Red fir are heavily infected with dwarf mistletoe (Arceuthobium abietinum f.sp. magnificae). Galleries made by the fir engraver (Scolytis ventralis) are present on boles. Cankers that appear to be due to Cytospora are present. Two root diseases, caused by Heterobasidion annosum (Fomes annosus) and Armillaria, are colonizing fir stumps throughout the area. Some lodgepole pine are infested with mountain pine beetle (Dendroctonus ponderosae). Several standing dead trees show conks of the pouch fungus, Polyporus volvatus, which causes a decay of sapwood.

2. "S" turn/ Weasal.

This area, covering 2 acres, extends on both sides of the road. The stand is similar to the one described in Tiegel area above, but with the addition of mountain hemlock in the understory and midstory. The understory is dense in spots and suppressed.

Snow-making equipment was installed in this area two years ago and there is a considerable amount of damage to the trees due to the severing and removal of tree roots during installation. Trees of all species are also dying in areas not affected by the disturbance. Annosus root disease, armillaria root disease and fir engraver were seen in the dead and dying red fir.

3. Lakeview.

This approximately 10 acre area lies near the top of Scott Peak (8200 feet). The Lakeview lift was installed in 1984 and trees were removed for lift

construction and run development. Currently, it is the policy of Alpine Meadows to apply borax to all freshly cut stumps for the prevention of annosus root disease. At the time this lift was installed, this policy was not in effect and boraxing was not done. Snow making equipment has not been installed.

The stand is predominately red fir and white fir, with some overstory ponderosa pine and mountain hemlock. Natural regeneration, mostly fir, is abundant. In general, trees are vigorous and show no above ground signs of pest activity. The stand is dense, with stocking exceeding 400 sq. ft. per acre at some locations. Pockets of mortality, (approximately 30-ft. in diameter) with 3 inch to 12 inch dbh white and red fir dead due to annosus root disease, are scattered throughout.

4. Hot Wheels Gully/ Lower Loop Road.

This area is approximately 3 acres and is split by an unpaved road. The stand is comprised of mountain hemlock, western white pine, and red fir. A creek runs through this gully. In years with normal precipitation the creek runs 12 months a year. Last year, due to the drought, the creek was dry by July. It is thought that this drop in water availability and drought conditions are stressing these trees making them susceptible to an array of insect and disease problems. The only alteration of the natural stand was the construction of the lower loop road.

There are many dead and dying mountain hemlock and western white pine in the area. Hemlock dwarf mistletoe (Arceuthobium tsugense) infection is severe. White pine blister rust (Cronartium ribicola) is present on western white pine. Red fir are impacted by a complex of dwarf mistletoe, a branch canker caused by Cytospora, armillaria root disease, annosus root disease, and fir engraver. Western white pine is infested with mountain pine beetle. Fomes pinicola, a decay fungus, is common on dead woody debris.

DISCUSSION

Methods used for road, ski run, and lift construction, snow making and grooming, all impact the health of the stands they are built through. This section summarizes the current maintenance practices in use, explains their impact on stand vigor and suggests ways of modifying these practices in order to minimize tree injury.

Construction impacts

When roads, lifts and runs are constructed some tree removal is necessary. This creates stumps and woody debris that can provide a favorable habitat for development of pests. Annosus root disease, which is present in spots throughout the ski area, spreads locally through root - to - root contact and into un-infested locations via spore infection of freshly cut stumps. This can be prevented in areas where the fungus is not already present by boraxing

stumps (see Heterobasidion annosum in the Pest Biology section for further details).

Insect population build up can also be a problem in cut boles. Lodgepole pine and other thin-barked species can be solarized to kill broods. This will not be an effective treatment in thick-barked species such as red fir. For further details see pest specific biologies section.

The piling of heavy objects, scraping of trunks, burial of root collars and compacting of soil due to heavy equipment operation all can contribute to the death of a tree (see Fig. 2). Even a "small" amount of damage can be significant, especially in periods of drought. Damage has a cumulative impact, each small injury weakens the tree, making it more susceptible to insects and diseases.

Snow making

One hundred sixty acres of the ski area are piped for snow making. There are 3 ponds with a holding capacity of 5 million gallons. A well and spring were developed last year in conjunction with the Alpine Meadows Spring Water District. Two water tanks with 100,000 and 500,000 gallon capacity are also on site.

The water is used to make snow in the winter and irrigate the runs in the summer. Irrigation helps stabilize the slopes and minimize erosion by promoting vegetation. Summer irrigation and winter snow making may ease drought stress on the trees in areas where it is applied.

The snow-making system extends from the ponds, via a series of pipes, up to the ski runs. Hoses are then extended from hydrants and snow can be made from 50-200 feet away.

To protect skiers from impact into hydrants, to protect hydrants from snow, and to maintain visual appeal, the pipes and hydrants were installed using natural and artificial barricades. Man-made barricades are typically lift towers. Natural barricades are usually clumps of trees. Where soil conditions allow, the pipe is buried. During installation, many tree roots were severed and removed. Mortality has occurred directly adjacent to pipelines. (see Fig. 3 & 4) Damage is due to injury incurred during pipeline installation. Damaged trees may remain alive for one or more years after injury depending on severity of damage. The drought conditions of the past few years is stressing trees and causing weakened trees to die.

Once a tree dies it must be removed for safety and aesthetic reasons. The removal of the tree also eliminates the barricade thereby destroying skier and hydrant protection. Additional damage may be done at the time of dead tree removal, making it more likely that neighboring trees will die.

It is apparent that using trees as barricades for snow making equipment is not an ideal solution to the protection problem. In areas where runs are wide, pipes could be buried no closer than 20 feet from standing trees. In areas where this is not practical, the pipe placement should be evaluated as to whether it is really necessary. If there is no alternative location available,

placing pipe on one side of a clump of trees is preferable to placing it in the middle of a group. It should be recognized that there is a high likelihood that trees adjacent to buried pipes will be killed and will need to be removed in the future, especially during periods of drought.

Once a tree is injured there is little that can be done to remedy the situation. The key to a healthy forest is damage prevention. As the snow-making capability is expanded into new areas, similar losses will occur unless the above outlined precautions are taken.

Salting

Grooming techniques used at Alpine Meadows includes the application of rock salt (NaCl) to the snow. This is done in the spring when snow is no longer freezing at night. The salt firms the snow, allowing the heavy grooming equipment to climb up the mountain. No more than 100 pounds per acre are applied in a 24 hour period. In total, 50,000 pounds of salt were applied last year. Some of this salt is used to groom race courses and other special uses, but the majority is broadcast over the 300-400 groomed acres. Due to manpower and equipment limitations and as a safety precaution, areas do not receive salt on consecutive days. At most they are treated every second or third day as conditions warrant.

Water samples are taken to monitor salt levels in water running off the resort. The samples have always been below a problem level.

Most of the areas that are salted are wide runs with few to no trees present. In our observations of trees at Alpine Meadows we did not see any trees with damage characteristic of salt toxicity.

The toxicity of salt to conifers has been well documented. This year, damage and mortality due to salt is evident along highways in the Lake Tahoe Basin and other areas where salt has been used for de-icing and snow removal (Kliejunas et. al., 1989).

Due to the potential for salt damage, careful monitoring should be continued and salt use kept to a minimum.

MANAGEMENT ALTERNATIVES

1. Do nothing. In stands with few pest problems and with appropriate stocking levels and adequate regeneration, the Lakeview area for example, can be expected to maintain themselves for several decades. Basal area will gradually increase over time and thinning may become desirable.

In overstocked stands with dwarf mistletoe and/or annosus root disease, tree mortality will continue to fluctuate with yearly precipitation levels. Top-killing and mortality of fir will occur as a result of a complex of diseases and insects, principally the fir engraver.

Mortality due to man-caused injury will also continue to occur among trees whose root systems are injured in construction projects.

Even though mortality will continue, the general stand appearance will remain similar to current conditions. Specific areas may change as small openings are created and regenerate.

2. Alter maintenance operations to protect stand health and vigor. Use only man made barricades to protect snow making equipment. Install pipes at least 20 feet from standing trees. Do not pile debris, scrape trunks, bury root collars or compact soil around the base of trees. Keep salt use to a minimum. See additional comments in discussion section of this report.

3. Develop and implement a vegetation management plan for the ski area. To ensure that forest visitors receive quality outdoor recreation within environmentally sound ski area developments, vegetative management plans could be written. Plans include management objectives for the entire area, and stand exams and stand prescriptions for stands within and adjacent to the ski area. The objectives of vegetation management plans include: maintain the existing forested landscape; improve the health and vigor of existing vegetation; and provide for a continuous succession of vegetation. Stand specific goals are also formulated. Typical stand objectives are: reduce risk due to dwarf mistletoe, root disease and bark beetles through stocking control or species conversion; maintain a diversity of hardwoods in the understory; and maintain or enhance vertical and horizontal diversity. Biological evaluations of insect and disease impacts are included to assess how pests might affect these goals.

The guidance contained in a vegetation management plan ensures that thinning, sanitation, regeneration and other activities are implemented in a timely manner.

4. Hazard tree management. The periodic inspection and treatment of trees that pose a threat to human safety or investments is already occurring at Alpine Meadows. Trees injured by construction, particularly true fir, are likely to become infected with root and butt rot, and are more susceptible to insect attack. Trees with dead tops are prone to infection by decay fungi and may become hazardous to skiers. The completion of hazard tree inspections and removal of suspect trees in a thorough and timely manner is advised.

PEST-SPECIFIC ALTERNATIVES

Pest-specific alternatives for annosus root disease, dwarf mistletoe, and bark and engraver beetles are presented below.

1. Annosus root disease. No direct methods are currently available for controlling or eliminating annosus root disease once it is established in a stand. Strategies available to reduce the impacts of Heterobasidion annosum include taking action to prevent the initiation of new centers by reducing the probability of stump infection, and implementing silvicultural treatments in infested stands to minimize disease effects. Alternatives include the following:

a. Prevent stump infection. Application of granular borax to freshly cut conifer stumps is effective in preventing most (90%) new infections. The chemical is toxic to the spores of H. annosum, but has no effect on existing infections. Borax application within a few hours of tree felling is required

on all conifer stumps created in and near developed recreation sites (FSM R-5 Supp. 164, FSM 2303.14, 9/86).

b. Regulate species composition. This alternative involves revegetating the opening created by the root disease-related mortality with species not susceptible to H. annosum. Heterobasidion annosum is host specific. Observations indicate that H. annosum centers in true fir can be successfully regenerated with pines and H. annosum centers in pine can be successfully planted with fir. These recommendations are based on laboratory tests and have not been fully verified in the field. Another option for revegetating active annosum centers is with non-susceptible hardwood or shrubs.

c. Utilization of openings. It is possible to use openings created by root disease for parking lots, ski runs, picnic areas, or administrative sites. Some mortality, creating potentially hazardous tree conditions, may occur around the edges of these areas.

2. Dwarf Mistletoe. The long-term effect of dwarf mistletoe is decadence and possible loss of the host species stand component. A series of actions are possible in high value areas to reduce the impact and intensity of the mistletoe and retain the natural appearance of the stand.

Dwarf mistletoe treatments may include one or any combination of the following:

1. Removing infected overstory trees to protect regeneration.
2. Removing witches' brooms to prolong tree life.
3. Removing all infections by pruning to eliminate the parasite.
4. Removing heavily infected trees that can not be successfully pruned.
5. Thinning to remove infected trees and release residual trees.
6. Destroying heavily infected stands or aggregations and then regenerating.
7. Creating buffer strips to prevent reentry of dwarf mistletoe.
8. Favoring resistant species (includes planting).

Forest Pest Management may be able to financially assist pre-suppression surveys designed to gather mistletoe information and for subsequent suppression projects. When funding pre-suppression surveys, we assume the Forest and District are committed to using the information to develop strategies for reducing pest impact. Forest Pest Management is available to provide assistance or additional information requested by the District or Forest.

3. Bark and Engaver Beetle Control Strategies. The best strategy for minimizing bark and engraver beetle damage to trees is the removal of decadent, weakened, or damaged trees and improvement of the growth and vigor of the residual trees. Damage to trees, especially to tree roots, can be prevented by avoiding excavating soil near the trees, compacting soil by running heavy equipment near the trees, piling heavy objects or debris near the root-collars of trees, or disturbing the root-crown balance of the trees. Stands which are 90%+ of normal basal area should be thinned to prevent the build up of stand stress that could cause serious bark beetle mortality. The density of these stands should be reduced to about 55% of normal basal area to maximize stand vigor. Thinning should be from below.

a. Slash treatment. Slash treatment, in conjunction with cutting operations will significantly reduce the potential of serious damage occurring to residual trees from pine engraver and to a lesser extent, from fir engraver populations that can develop in the green slash. Because pine engraver beetles can complete their development in about one month under ideal conditions, treatment should be carried out soon after cutting to be effective. Utilization of the cut material to the smallest possible diameter will minimize the amount of breeding material available to these beetles. Engraver broods require green stem and branch material 3 inches and larger in diameter to successfully survive and develop.

Timing of cutting operations is very important in preventing engraver beetle damage. The timing of woods operations to incur minimum risk of sustaining tree damage from pine engraver beetles, Ips sp., is from mid-July through the end of December. If done at this time, the green slash has a high probability of drying out, heating up, or spoiling before the pine engraver beetles can complete their development and emerge from the slash to attack living trees. The season of high risk for cutting operations for pine engraver beetles is from the first of February through mid-July. The period of low risk for damage by fir engraver, Scolytus ventralis, is the first of October through the end of February. If cutting operations are required outside this period of minimum risk, slash treatment measures should be considered to prevent the emergent of the engraver beetles or serious damage to living trees in the area may result.

Slash treatment methods which generally work well include: chipping; lopping and scattering slash in sunny areas to dry it out; crushing or mashing slash with logging equipment to make it unsuitable for engraver breeding; or piling and burning the slash within one month of cutting. Broadcast burning the slash might work if it could be done without damaging the residual trees. A method which has worked during the summer months in hot climates is to pile slash in sunny areas and tightly cover the piles of slash with clear plastic. If the temperature under the bark of the slash reaches 120 F, all broods currently in the slash will be killed. Because most engraver beetle attacks occur within a quarter-mile from the location where the beetles emerged, high value trees can be given some protection by removing fresh slash to areas that do not have the host trees. Two practices which should generally be avoided are piling fresh slash without further treatment, which usually prevents the slash from drying out enough to prevent beetle emergence, and allowing slash to touch or remain near valuable living trees, which increases their chances of being attacked by the engraver beetles if they emerge.

A serious problem with the lopping and scattering method of slash treatment is that in most woods operations, the slash is not reduced to fine enough pieces to allow them to dry out. To minimize insect buildup, logging slash should be lopped to sizes no larger than a 3-inch top and scattered to a maximum height of 18 inches above the ground.

b. Protective sprays. Insecticides used for direct control or preventive sprays are reviewed periodically by the Environmental Protection Agency. If the decision is made to use insecticides, the names of materials currently registered for use, if any are, can be obtained from our office or any Forest Pest Management Office within this Region.

PEST BIOLOGIES

ANNOSUS ROOT DISEASE

Heterobasidion annosum (Fomes annosus) is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (Artemisia menziesii), and a few brush species (Arctostaphylos spp. and Artemisia tridentata) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, H. annosum grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from H. annosum are mainly the result of windthrow resulting from root decay, and reduced root systems which predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

H. annosum infections probably do not cross from roots of pine to roots of true fir or from roots of fir to pine. At higher elevations where pine and true fir are intermixed, H. annosum is commonly found only on true fir and mortality rarely includes both species within an infection center.

ARMILLARIA ROOT ROT

Armillaria sp. is widely distributed in soils and usually lives as a saprophyte on dead wood or other organic matter. This fungus has a wide host range, including virtually all woody plants in California. It is frequently associated with hardwood roots, especially oaks. Healthy oaks are resistant to the fungus. This resistance disappears, however, when trees are weakened, stressed, cut, or killed, and Armillaria sp. may then rapidly colonize and decompose

roots and sometimes entire root systems. Stresses that have been linked to increased damage from this root disease include insect defoliation, drought, excessive soil moisture, poor planting techniques, bark beetle attack, air pollution injury, and nutrient deficiencies.

The organic material used as a source of nutrition is called a food base. With a large food base to utilize, the fungus becomes more aggressive and moves to the roots of nearby trees by means of root contacts and rhizomorphs. Rhizomorphs are structures that resemble black shoestrings and grow like roots through upper soil layers. The predominant method of tree to tree spread in California is via root contact; rhizomorphs are more important and prevalent in other areas of the country.

Armillaria sp. is capable of directly penetrating through the intact root bark of living trees and once it reaches the cambium it usually grows rapidly, producing a flat, white, leathery, fan-shaped mycelial mat. Rhizomorphs are often associated with the mat. If the fungus reaches the root collar it girdles the stem and kills the tree. After Armillaria sp. successfully colonizes a root segment or root system, it continues to decay the wood and causes a white to yellowish, wet, stringy rot. This rot does not usually extend more than a few feet above the soil line.

Clusters of mushrooms may be found in the fall at the base of infected dead or dying trees and stumps. These mushrooms may also grow directly out of the soil near the food base. Spores produced by fruiting bodies are not an important source of new infections or long distance spread.

CYTOSPORA CANKER

Cytospora abietis is a canker-causing fungus that infects true firs throughout their range in California. It is a weak parasite, and usually attacks trees that have been weakened by disease, drought, fire, insects, or human disturbance. It is most commonly associated with dwarf mistletoe infection, and sometimes attacks as many as a quarter of the mistletoe-bearing branches, killing many each year. The bright red flags of recently-killed branches on dwarf mistletoe-infected red firs are almost always the result of lethal Cytospora infections. C. abietis occasionally reaches especially damaging proportions in certain years, and may attack trees of any age, sometimes killing the tops or all of young trees.

DWARF MISTLETOE

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a

seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occasionally vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of Digger pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

WHITE PINE BLISTER RUST

White pine blister rust (Cronartium ribicola) is caused by an obligate parasite that attacks sugar and western white pines and several species of Ribes. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needed pines and the other on Ribes. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to Ribes where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other Ribes throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes leaves in the fall. Teliospores germinate in place to produce spores (sporidia) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes, its spread from Ribes back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers whose closest margins are more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.

Environmental conditions are critical for successful infection and limit the disease most years. Moisture and low temperatures favor infection of both hosts, and must coincide with spore dispersal for infection to occur. In California, these conditions occur only infrequently, usually in cool moist sites such as stream bottoms or around meadows. In so, called "wave years" when favorable conditions occur, high levels of infection can result. Wave years in California have occurred at approximately ten-year intervals in the past. As one moves from sites most favorable for rust to less favorable sites, the frequency of wave years decreases.

FIR ENGRAVER

The fir engraver (*Scolytus ventralis*) attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after the beetles have emerged.

PINE ENGRAVER

The pine engraver (*Ips* sp.) is distributed extensively in the forests of the west where it breeds in almost any species of pine. Large numbers develop in such host material as windfalls, freshly cut logs, slash over 2 inches in diameter, and the tops and limbs of trees, especially those killed by Dendroctonus bark beetles. When suitable host material is plentiful, they frequently develop in such numbers as to become aggressive in their attacks on healthy trees. Damage often follows droughty spring weather. Outbreaks are usually of short duration and seldom last more than one season. The most frequent damage is in the killing of young replacement trees from 2 to 8 inches in diameter and top killing older trees. During outbreaks, group killing becomes widespread.

The adults are reddish brown to nearly black and from 3.5 to 4.2 mm long. There are from one to five generations per year, depending on the locality and length of season. The parent adults often emerge and make a second or third attack, causing a confusing overlap of broods.

Preventing these beetles from becoming too numerous through timely slash disposal and thinning of dense stands will do more to prevent damage than the application of direct control measures after damage has occurred.

MOUNTAIN PINE BEETLE

The mountain pine beetle, Dendroctonus ponderosae, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 4 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is the general rule, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine.

Attacks may extend from the root collar up to near the top. Pheromones released during a successful attack may attract enough beetles to result in a group kill. Pitch tubes and red boring dust in bark crevices or on the ground indicate successful attacks.

The adults bore long vertical egg galleries and lay eggs in niches along the sides of the gallery. A "J"-hook is common at the lower end of the gallery. The hatching larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

The sapwood of successfully attacked trees soon becomes heavily bluestained. The bluestain fungi probably aid in overcoming the defenses of the host tree.

Natural factors affecting the abundance of the mountain pine beetle include low winter temperatures, nematodes, woodpeckers and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and mortality increases. Relieving stress by thinning dense stands can prevent some group kills. Individual high value trees undergoing temporary reversible stress may be protected from attack by application of insecticide to the bole.

LITERATURE CITED

1. Kliejunas, J., Marosy, M., and J. Pronos. 1989. Conifer damage and mortality associated with highway de-icing and snow removal in the Lake Tahoe Area. Report No. 89-11. USDA Forest Service, Pacific Southwest Region. 18 p.
2. Patterson, J.E. 1930. Control of the Mountain Pine Beetle in Lodgepole Pine by the use of Solar Heat. USDA Tech. Bull. 195, Washington D.C. 20 p.



Figure 1. Tree mortality in the area of
Alpine Meadows Ski Resort.



Figure 2. Soil compaction and debris piled
at the root collar of trees.



Figure 3. Tree root disturbance
in association with a
water line.

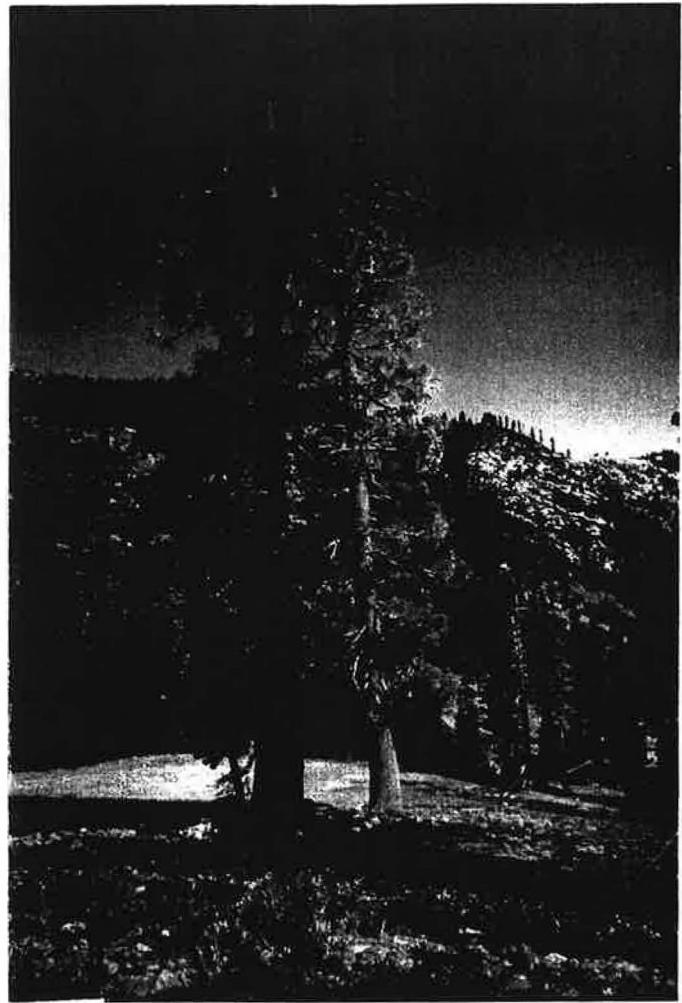


Figure 4. Four groups of tree
mortality in assoc-
iation with the water
line.

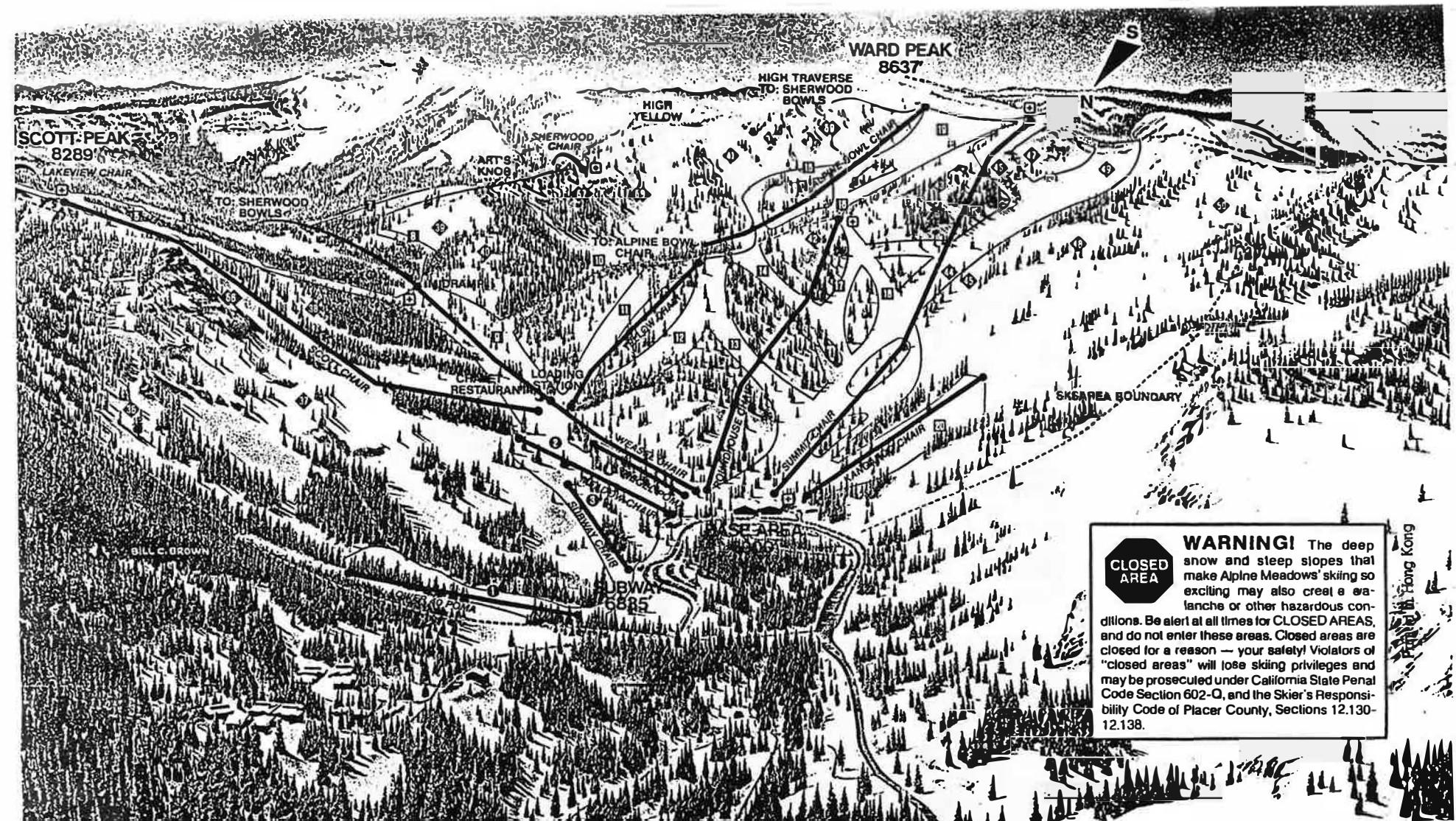


Fig. 5. Alpine Meadows Ski Area, Truckee Ranger District, Tahoe National Forest.

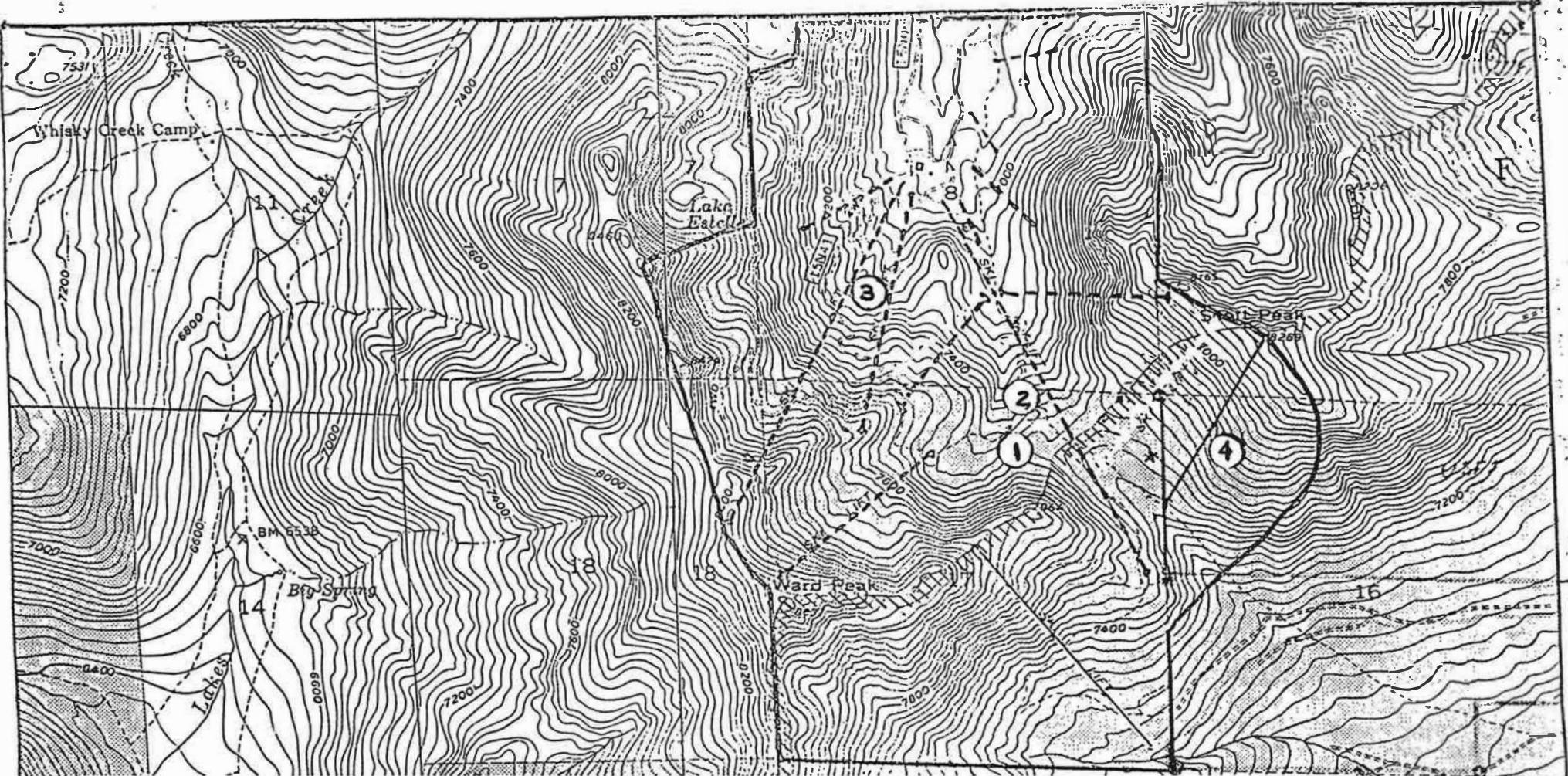


Fig. 6. Location of areas examined at Alpine Meadows. 1. Area adjacent to Tiegel Poma. 2. S turn/ Weasal. 3. Lakeview. 4. Hot Wheels Gully/ Lower Loop Road.

SKI AREA BOUNDARY



SKI LIFTS



